Net Sequestration Potential (NSP) & Atmos Reporting

A New Method for Measuring Biogenic Carbon

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PAE

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Executive Summary

Trees are foundational organisms in addressing the climate crisis. They are some of the most important plants on the planet in part due to their ability to breathe in CO_2 and store it long term in their bodies. Despite their importance as a climate solution, methods to account for their benefits are often neither consistent nor accurate representations of reality. In addition, some methods of carbon accounting dramatically over estimate the benefits of consuming trees for material use and fuel stocks. Existing quantitative measurements for the carbon impact of wood products do not account for differences in forest management practices.

If we are to encourage the use of trees as a climate solution it is critical we accurately account for their benefits and encourage the development of forest practices that maximize sequestration potentials.

This paper estimates current biogenic carbon accounting methods can overestimate benefits by over 2 times and proposes three steps to improve biogenic carbon reporting:

— **FVS Simulation**
  A basis for calculating net biome production (NBP) in the absence of collected data via the free Forest Vegetation Simulator software from the United States Forest Service.

— **Net Sequestration Potential (NSP) Calculation**
  A means of translating NBP carbon flows from the stand to harvested wood products.

— **Atmos Reporting Method**
  Rules for reporting NSP in conventional static LCA stages.

These three steps use methods that better reflect the influence of forest management practices, the time of emissions, and the uncertainty around regrowth in order to more accurately estimate the carbon impacts today's wood products have on the future climate.

We believe the use of wood is still important as a carbon storage strategy but the values used in current carbon accounting models should be revisited to better measure the true impacts of the use of wood in the built environment.

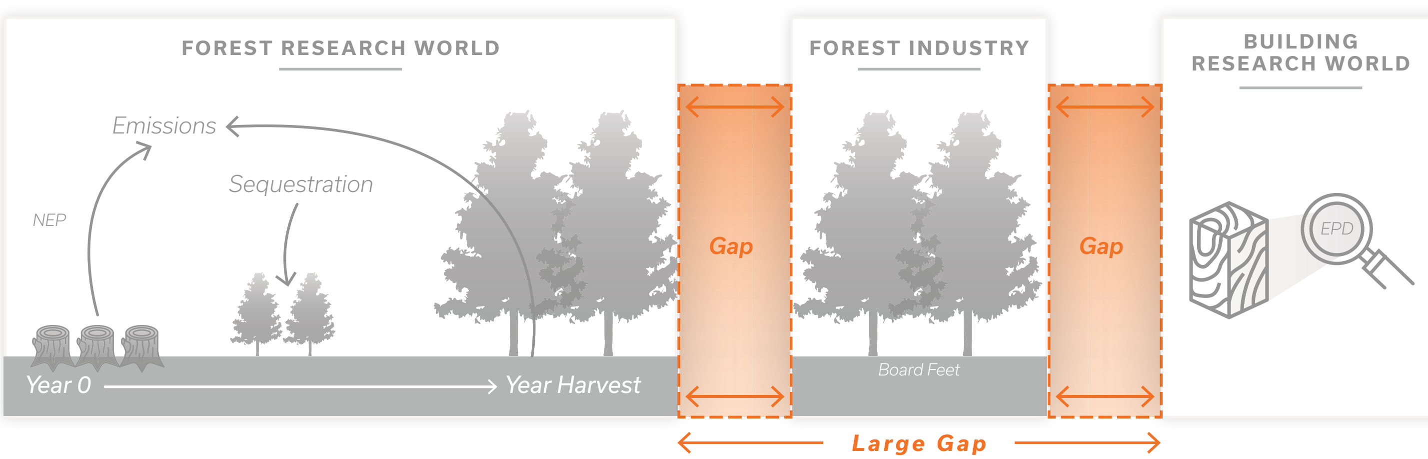
Note that forests are multifaceted ecosystems and play multiple roles in safe-guarding our environment. This paper dives into one of those facets: carbon. As such, it is important to acknowledge that improving our understanding of carbon impacts does not negate the need for improved understanding among the many other facets of forests, such as their value for watershed protection or wildlife habitat.

THROUGH OUR RESEARCH WE HAVE FOUND THE FOLLOWING KEY INSIGHTS:

— Carbon accounting for current Environmental Product Declarations (EPDs) and LCA softwares overestimate storage by over 2 times in the A-B stages.

— Current EPDs and LCA softwares do not accurately reflect when emissions go to atmosphere and when they are sequestered. The proposed methodology addresses this by revising inputs and reporting for LCA studies.

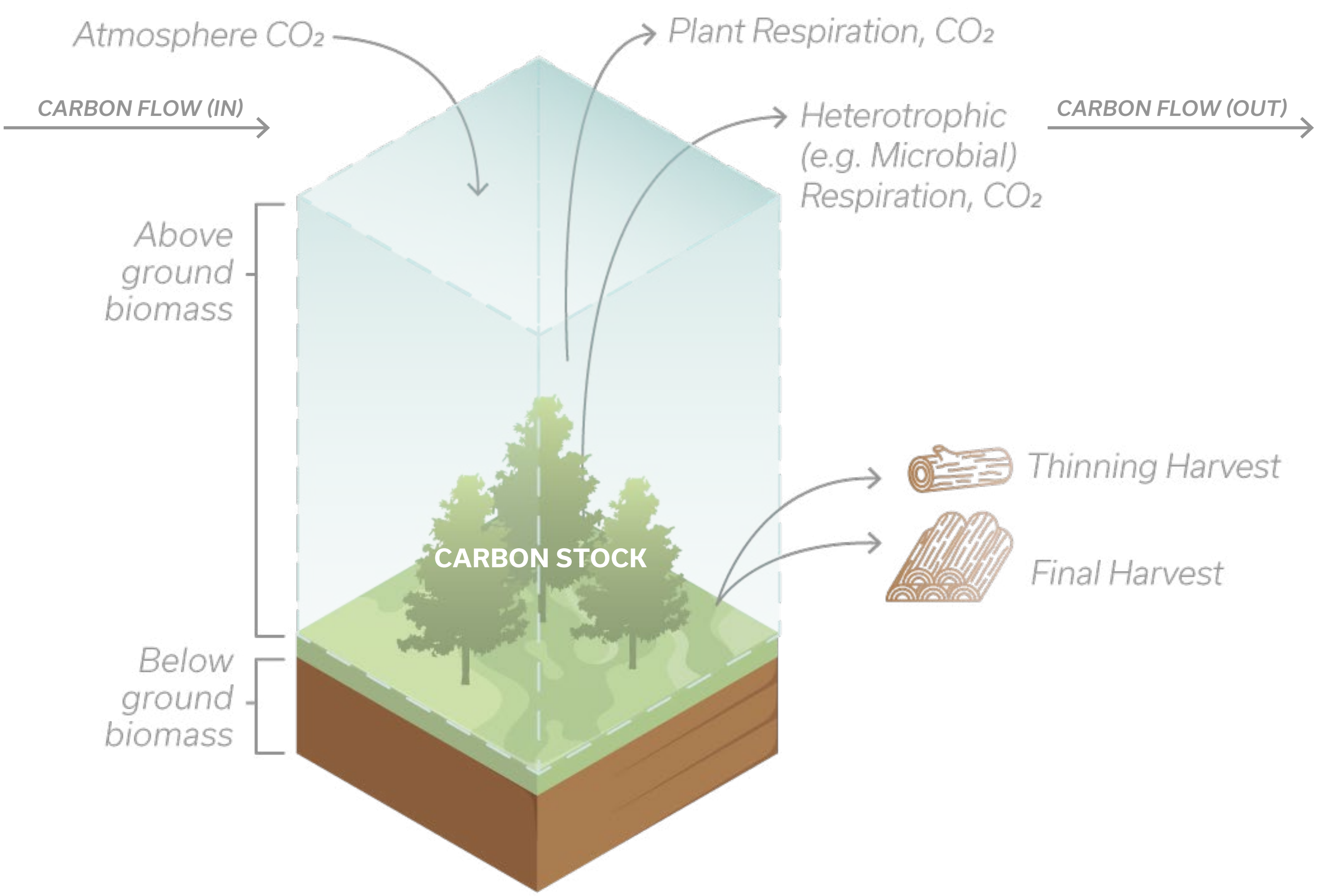
— Current EPDs and LCA softwares do not account for the effects of different forest management practices in biogenic carbon calculations and reporting. The proposed methodology addresses this by basing calculations on carbon flows at the stand.



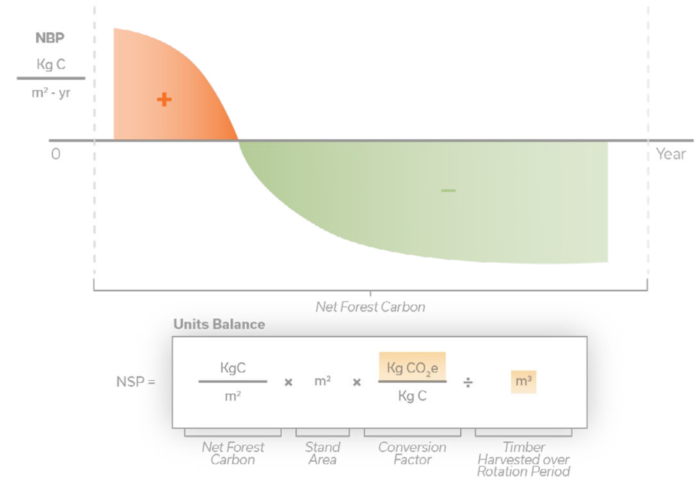
Holistic Biogenic Carbon & NSP

Biogenic carbon refers to carbon from biological sources. In a forest, biogenic carbon is stored in organic matter which is sequestered from the atmosphere through plants via photosynthesis and released through the respiration of those same plants and the respiration of microbes and invertebrates as organic matter biodegrades. In this way carbon at any single point in time exists both as a stock, physically fixed in the forest or in wood products, and as a flow in and out of the forest system.

The Net Sequestration Potential (NSP) metric proposed in this paper attempts to create a more holistic approach to measuring biogenic carbon. It does this by measuring carbon flows more directly based on where they occur. NSP establishes a methodology to account for the emissions from soil disturbances from different forestry practices. Forest soil disturbances affect carbon flows that are currently excluded from wood product EPDs and life-cycle assessment (LCA) softwares.



The Net Sequestration Potential Solution (NSP)



In order to improve the measurement of sequestration benefits of wood products PAE created a new metric during our research called NSP (Net Sequestration Potential). This metric accounts for carbon flows at the stand over the harvest cycle. NSP is typically net-positive (indicating net emissions to atmosphere) after a clearcut for ~10 years before balance swings back to net-negative (indicating net sequestration from atmosphere).

The goal of NSP is to unify the two different industries with a metric that is focused on net carbon sequestration. This is very important as the units tend to be focused on wood products harvested or ecosystem production but they don't consolidate impacts from the forest to the product. Sequestration rates need to be a top priority to help create a net zero future.

x2.3 - x2.5

Ignored biogenic emissions could mean current sequestration values are overestimated by a factor greater than 2 on average across the A-B stages.

~41%

Slash can emit around 41% the of the net amount sequestered.

per NSP calculation using FVS software, outlined on page 12

Dynamic vs. Static LCAs

Emissions happen dynamically, that is they are released over a period of time and their impact to the atmosphere changes over an even longer period of time. Dynamic life-cycle assessments take this into account by reflecting the quantity, duration, and time of emissions to determine effects. Dynamic LCAs also address changing environmental factors. Biogenic carbon would be best represented by a dynamic LCA, which excels at showing the temporal scope and impacts of any emissions analyzed, however it has thus far been considered too complex for broad adoption.

Conventional LCA practice reduces emissions to discrete static values for ease of calculation and reporting. Emissions are categorized into different stages, each stage reflecting a phase in the life time of a product. The first stages reflect the early phases of a product's life span, with each subsequent phase reflecting later phases. In this way LCA stages are often perceived as a rough means of understanding time of emissions. However, this can pose an issue when dealing with emissions that occur over long periods of time and/or consolidating emissions from various materials of differing life spans as in a building LCA.

The proposed Atmos Reporting Method presented in the following pages, whereby sequestration is reduced to a static value and allocated to the B1 stage best utilizes the current standard reporting process to reflect future sequestration. Additionally, NBP curves used in the NSP methodology are reflective of net emissions over time and adoption of this as the basis of calculations provides a pathway for alignment with dynamic LCA if adopted more broadly in the future.

Atmos Reporting Method

PROPOSED REPORTING METHODOLOGY: ATMOS

Many LCAs, and certifications for embodied carbon in buildings focus on cradle-to-gate emissions (A1-A3) as these are the stages that design teams have the most influence over through product selection and there is greater uncertainty surrounding emissions in later stages that are subject to the future. As a result of this focus, the approach to accounting for biogenic carbon in these upfront stages is especially important.

Current accounting practices in EPDs overestimate carbon sequestration in the A1-A3 stages by:

— Ignoring forest-level emissions from soil and litter that vary with management practices.

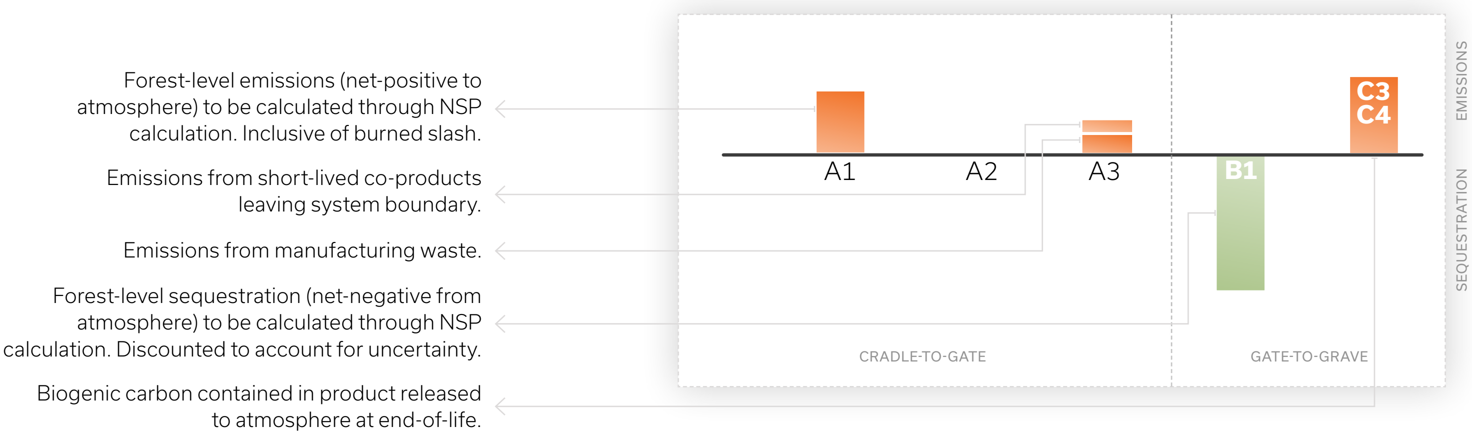
— Canceling out emissions from slash when reported by claiming equivalent sequestration upfront.

— Claiming sequestration of carbon that was removed from atmosphere decades ago. Thereby violating the intent to quantify additionally and future impacts.

In response to the first issue, this paper presents an alternative calculation called Net Sequestration Potential (NSP) which is designed to account for these previously neglected emissions through the net flow of carbon over the stand's life. In response to the second and third, we recommend using the proposed Atmos Reporting Method which focuses on emissions to and from atmosphere.

Per the Atmos method any credit for sequestered carbon would be allocated to the B1 stage at a discounted rate based on likelihood of successful regrowth. This reflects the carbon flow and stock of the materials and avoids over counting sequestration in the A stages. We recommend that A3 accounts for emissions from biogenic material (e.g. sawdust) burned during manufacturing, and counterbalances sequestration attributed to short-lived by-products. Additionally, we suggest calculating C4/C3 emissions from the product at end of life by counterbalancing sequestration attributed to the proportion of the product assumed to decompose in this stage.

Accounting for these emissions and sequestration in this way allows the existing conventional life-cycle stages to better reflect emissions and time of emissions to the atmosphere.



BIOGENIC CARBON COMPARISON FOR CROSS LAMINATED TIMBER

	TOTAL (A-C)	TOTAL (A-B)	A1	A2	A3	B1	C3/C4
EPD	0.00	-874.83	-969.71		94.88		874.83
TALLY LCA SOFTWARE	-607.91	-959.83		-959.83			351.92
NSP & ATMOS REPORTING*	208.77	-383.89	656.88		260.19	-1300.97	592.66

**Based on NSP calculated via FVS simulation for a 40yr clear-cut Douglas Fir stand with slash burned, 8% loss during manufacturing, 10% by-products, 0.9 CDF, and 50% of product returned to atmosphere at end-of-life. Note this example shows how the Atmos method has roughly 1/3 the sequestration in the A-B stages compared to EPD and Tally values*

INTEGRATING NSP & ATMOS REPORTING METHOD

This paper proposes three steps to improve biogenic carbon reporting:

- **FVS Simulation**
  A basis for calculating NBP in the absence of collected data via the free Forest Vegetation Simulator software from the United States Forest Service.

- **NSP Calculation**
  A means of translating NBP carbon flows from the stand to harvested wood products.

- **Atmos Reporting Method**
  Rules for reporting NSP in conventional LCA stages.

The Atmos method takes the NSP calculation and separates it into two pieces: early net-positive emissions and later net-negative emissions (sequestration). This allows us to address the three issues of current accounting practices but still use the general framework of reporting stages.

A1

Early net-positive emissions are placed directly in A1. Emissions during this period are largely driven by slash which is typically burned or left to decompose. Newly planted seedlings also take time to ramp up their sequestration.

A3

Emissions from biogenic manufacturing waste and short-lived by-products leaving the system boundary should be calculated as a counterbalance to the sequestration attributed to those materials.

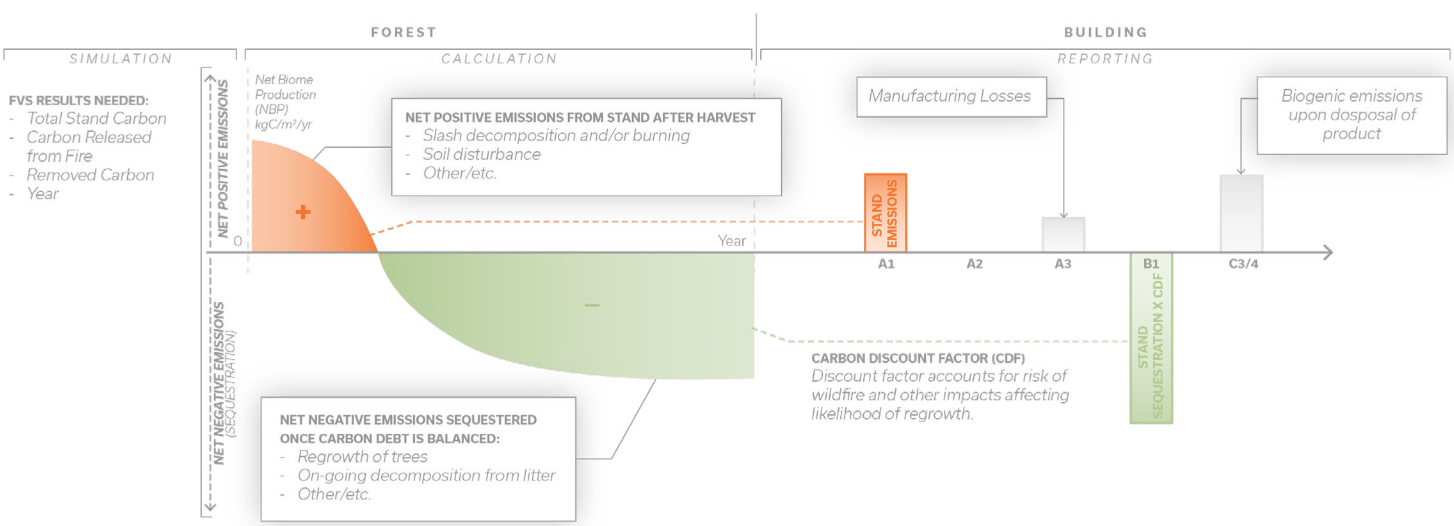
B1

Net-negative emissions (sequestration) are placed in B1. This is to reflect future regrowth of the stand which will be responsible for future impacts to the atmosphere (past growth is already realized in atmospheric levels).

In recognition of the uncertainty that regrowth will occur and succeed, a Carbon Discount Factor (CDF) is to be applied. This must at a minimum take into account the likelihood of wildfire and pest infestation, but should extend to other issues such as land-use change (e.g. conversion from industrial forest land to residential development).

C3/C4

Emissions from the product at end-of-life should be calculated as a counterbalance to the sequestration attributed to the portion of the product assumed to decompose.



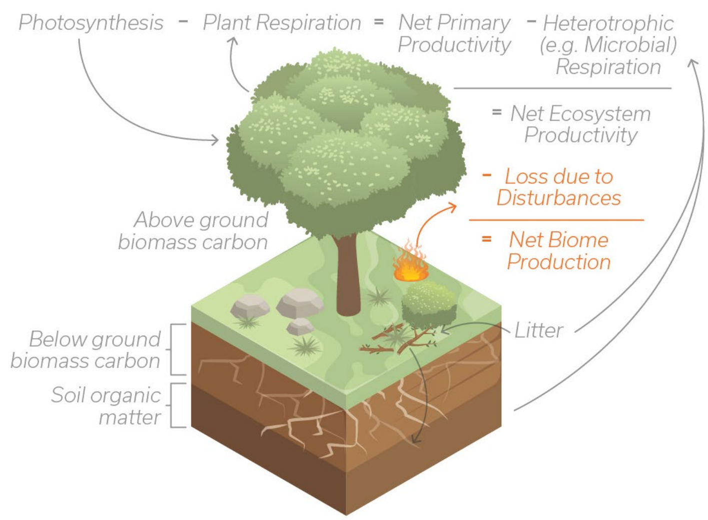
Net Sequestration Potential Calculation (NSP)

Carbon stocks build as result of carbon flows in a forest. Carbon in the form of carbon dioxide is pulled from the atmosphere through photosynthesis and is respired in the same form from plants at night. The balance between these two flows is called Net Primary Production (NPP) and is responsible for the accumulation of biomass. Carbon is also respired from heterotrophic respiration by microbes and other organisms in the decomposition of organic matter. The balance between NPP and microbial respiration is called Net Ecosystem Production (NEP). When carbon flows from disturbance are taken into account this results in Net Biome Production (NBP). NPP, NEP, and NBP are typically measured as an annual flow of carbon per area of forest in kgC/m^2/yr.

The proposed calculation methodology presented in this paper is intended to provide a fuller picture of carbon at the forest level and relate it back to the procured product. By using NBP as a basis for the carbon scope in the calculation we can include the variation of NBP flows over a rotation period – harvest to harvest. The principal motivation for this is to account for the impact of harvesting practices on net carbon sequestration/emission rates on the forest over the rotation period. Harvests will typically leave litter on the forest floor or burn it, disturb soil, and drastically reduce the stand's ability to photosynthesize and sequester leading to a swing in the balance between sequestration and biogenic emissions. The shorter the rotation period the less time forests have to recover from that disturbance and counter a 'carbon debt.'

The proposed calculation would quantify the accumulation of NBP from harvest to harvest – a net carbon value per unit area. To use real collected data, functions describing NBP would need to be developed based on NEP and/or NBP datasets and used to create tables of values that can be referenced when LCAs are conducted. Note that an alternative approach using simulated data from FVS is presented later in this paper which allows calculation without collected data.

Multiplying by the harvested stand area and a conversion factor (44/12) for elemental carbon to carbon dioxide equivalent provides a total net kgCO_2e sequestered over the rotation period. In order to relate this value to the wood harvested it must be divided by the total volume of timber harvested over that same period.

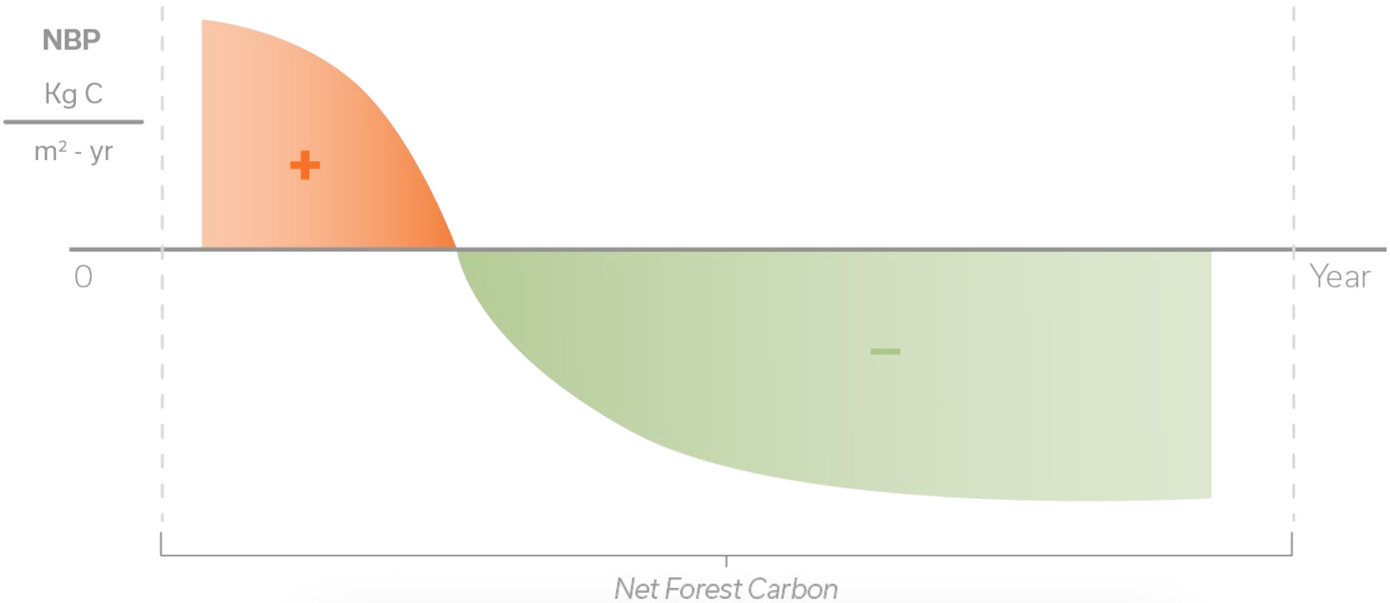


With the right data behind it, this methodology can account for biogenic emissions that occur on the landscape after harvest which is currently excluded from EPD and LCA software values. Emissions from clear cuts on short rotations could make a dent in the carbon benefit we account for in the product and subsequently in the building it is placed in.

LIMITATIONS

Datasets on NEP and NBP are often sparse and incomplete. The eddy covariance method is used to collect the data on site which requires prolonged coordination efforts and specialized equipment but is recognized as the preferred method for such measurements. It is unrealistic to expect most owners to collect this data at their forests, but ongoing research on forests and their management could provide relevant datasets or models that can be used as the foundation for a set of NBP curves over forest age to be referenced on the basis of harvesting practice, species, and site class. In the absence of such collected data, it is recommended that the forest carbon flows are simulated. A FVS Simulation method is presented later in this paper for this purpose.

NET SEQUESTRATION POTENTIAL (NSP) EQUATION



Units Balance

$$NSP = \underbrace{\frac{KgC}{m^2}}_{\text{Net Forest Carbon}} \times \underbrace{m^2}_{\text{Stand Area}} \times \underbrace{\frac{Kg\ CO_2e}{Kg\ C}}_{\text{Conversion Factor}} \div \underbrace{m^3}_{\text{Timber Harvested over Rotation Period}}$$

To be referenced from curves or calculated from FVS simulation

$$\text{net forest carbon} = \left(\int_o^h f_{NBP}(t)dt \right)$$

$$(\text{net forest carbon} \times A) \times \frac{44}{12} \times \frac{1}{Y}$$

***f_{NBP}* (t)** – Net Biome Production (NBP), *kgC/m²/yr*

h – harvest age, *yr*

t – time, *yr*

forest carbon - sequestered carbon in trees and soils over the rotation period, kgC/*m²*

A – harvested area, *m²*

Y – total timber yield over rotation period (yr 0 to yr h), *m³*

EXAMPLE OF INPUTS

The calculation methodology is developed with the intention that inputs are closely representative of the stand in which the wood in the product was grown. This requires a greater degree of transparency in the supply chain, and we highly encourage this be pursued. With that in mind, the following outlines where input data should be taken from:

NSP CALCULATION BASED ON COLLECTED DATA

- **Net Forest Carbon**
  Based on NBP curves from collected data reported in relevant academic papers, databases, or measured on site. In order to determine relevance of existing data the following must be known:
  - **Rotation Period**
    Find this from your forest manager or use published yield and growth curves to identify the financial age (when annual growth declines).
  - **Species and Region**
    Find this from the manufacturer's product description.
  - **Management Practice**
    Find this from your forest manager. Or identify regionally conventional practices.
- **Stand Area**
  Find through your forest manager or identify acres of forested land under the relevant county and ownership type. For example, for Washington state this data is reported by the Natural Resource Spatial Informatics Group (through the University of Washington).
- **Timber Harvested**
  Find from your forest manager, or identify average annual timber output for the relevant county and ownership type from state timber harvest reports and multiply by number of years for the assumed rotation period.
- **Conversion Factor**
  Use the conversion factor based on molecular weights (KgCO2e/KgC) = 44/12

NSP CALCULATION BASED ON FVS SIMULATION

- **Net Forest Carbon x Stand Area**
  FVS software can report out values equivalent to net forest carbon times stand area for each simulated stand. In order to ensure simulation is as relevant as possible the following must be known:
  - **Rotation Period**
    Find this from your forest manager or use published yield and growth curves to identify the financial age (when annual growth declines).
  - **Species and Region**
    Find this from the manufacturer's product description.
  - **Management Practice**
    Find this from your forest manager. Or identify regionally conventional practices.
- **Timber Harvested**
  FVS software can report out harvested volumes for each simulated stand.
- **Conversion Factor**
  Use the conversion factor based on molecular weights (KgCO2e/KgC) = 44/12

SPATIAL AND TEMPORAL BOUNDARIES

As with any calculation based on flows, defining the boundaries of the assessment is important. Thus far, the NSP calculation has been discussed largely with the traditional clear-cut practice in mind where we assume the entire stand is cut down in one fell swoop. This is not, however, always the case. For example, some stands are managed with thinning, wherein a selective cut is made to remove a portion of trees in, say, year 30 to improve the growth of the remaining trees which are then cut, say, in year 40. A portion of trees may also be excluded from harvest entirely, for example trees that make up a riparian buffer around waterways.

The following outlines PAE's recommendations on spatial and temporal boundaries for the calculation of NSP:

SPATIAL BOUNDARY

While the width and maintenance of a riparian buffer or similar reserved patch of land can be a decision made by a forest manager and offers benefits in maintaining carbon on the landscape, reducing effects of runoff, and maintaining habitat, it can likewise be a necessitated effect of the physical landscape or legal regulations. Note that inclusion of these areas would require extraordinary traceability to the stand which is not yet feasible for most. They are also by definition excluded from the production of wood products. For these reasons, we recommend that the spatial boundary be focused in on harvested areas only.

TEMPORAL BOUNDARY

For cases where harvest occurs in various stages, the temporal boundary would cover the overarching cyclical period after which all trees have been harvested. In the case presented wherein thinning occurs at year 20 and remaining trees are harvested at year 40, the temporal scope would range from year 0 to year 40. Total carbon flows and harvested volumes over that period would be included.

FVS Simulation for NSP

In theory, collected data is ideal for the calculation of NSP. However, in reality we have found it difficult to identify available databases of NEP or NBP. Data that is available is sparse and reflective of particular conditions that may or may not suit the forest type in question. As such, we have developed a simulation methodology using the Forest Vegetation Simulator (FVS) software from the USDA Forest Service, which is free and publicly available. As a simulation, the accuracy of results is inherently dependent on the assumptions used and the calculations used by the software. We acknowledge this as an imperfect, but plausible approximation.

The FVS software includes inventory of real-life stands across various regions and allows users to simulate various management strategies including, natural sprouting, planting, thinning, clear cutting, and various fire scenarios.

To avoid simulated emissions reflecting changes from inventory conditions two complete harvest cycles are simulated. The first is used to establish the conditions under which harvest occurs, the second to simulate the regrowth of planted trees. NSP is calculated based on the second cycle beginning immediately after first harvest. In this way it is inclusive of pile burning or decomposition of slash.

For this paper, a clearcut management approach was simulated with and without pile burning for comparison. Results were pulled using the carbon stand tables.

To approximate the integral of NBP, a slicing method is used where the change in total stand carbon and any carbon released from fire over each reporting interval is taken and summed. For accuracy, annual reporting is ideal, however FVS is limited to 40 reporting data points. Given this, the smallest possible slicing interval is to be used.

Note that because the FVS stand carbon pools exclude soil, it is possible the values obtained are more optimistic than NSP based on collected data which would capture emissions from soil more directly.

Another option to calculate NSP could be using standard estimates of forest ecosystem carbon provided by the USDA Forest Service. These are forest carbon lookup tables of common U.S. forest types based on FVS simulations. This paper doesn't delve into the specifics of using these tables but it is expected that similar results could be achieved. Refer to "Standard estimates of forest ecosystem carbon for forest types of the United States" by Hoover, Bagdon and Gagnon, 2021 for the tables.

GENERAL INPUTS

Variant: West Cascades
Forest Type: Douglas fir, 201
Stands: all 92 stands simulated.

SIMULATION DESCRIPTION (40-YEAR ROTATION, SLASH BURNED)

Clearcut followed by pile burn

Existing stands cut in 2020, with slash left and pile burned same year followed by replanting of Douglas fir at 300 trees per acre. First harvest done in 2060 and pile burned same year followed by replanting of Douglas fir at 300 trees per acre. Reporting every 4 years until 2100.

SIMULATION DESCRIPTION (40-YEAR ROTATION, SLASH DECOMPOSED)

Clearcut with slash left on-site

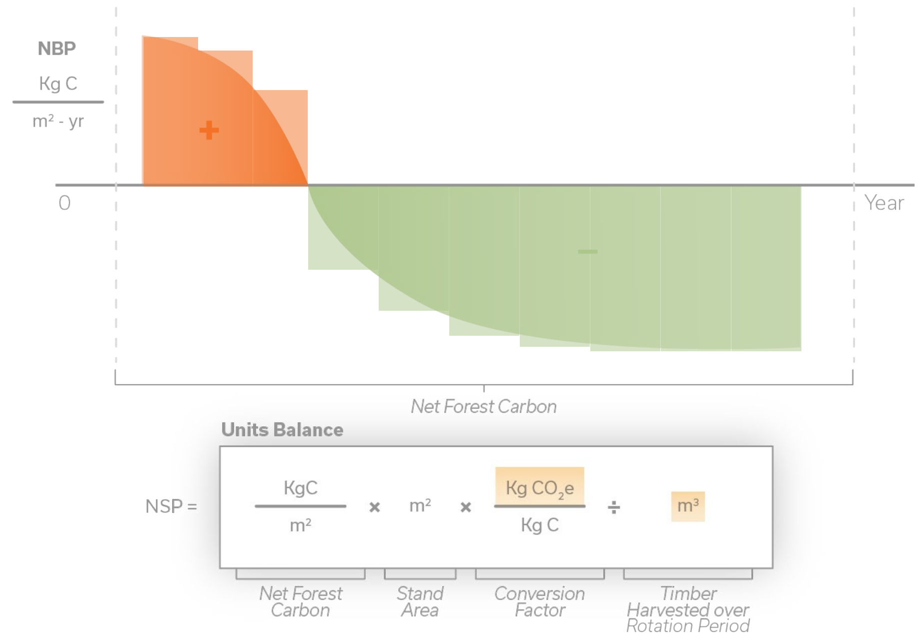
Existing stands cut in 2020, with slash left on site. Followed by replanting of Douglas fir at 300 trees per acre. First harvest done in 2060 and pile burned same year followed by replanting of Douglas fir at 300 trees per acre. Reporting every 4 years until 2100.

FVS OUTPUTS FOR NSP CALCULATION

- **Total Stand Carbon**
  This is the sum of all simulated carbon pools. Use the change in this in conjunction with Carbon Released from Fire to approximate the integral of NBP (i.e. Net Forest Carbon). Pools covered are:
  - **Above Ground Live Biomass**
  - **Below Ground Live Biomass (Coarse Roots)**
  - **Below Ground Dead Biomass (Coarse Roots)**
  - **Standing Dead Wood**
  - **Down Dead Wood**
  - **Forest Floor (Litter and Duff)**
  - **Forest Shrubs and Herbs**
- **Carbon Released From Fire**
  This is carbon released from the simulated fire events, e.g. pile burns. Use this in conjunction with Total Stand Carbon to calculate NBP.
- **Removed Carbon**
  This is carbon removed from the stand via harvest. Use this to calculate the harvested volume of wood using the wood species' density and the industry standard assumption that 50% of wood mass is carbon.
- **Year**
  This indicates the year of each reported data point. Use this to identify the data points of your second harvest cycle.

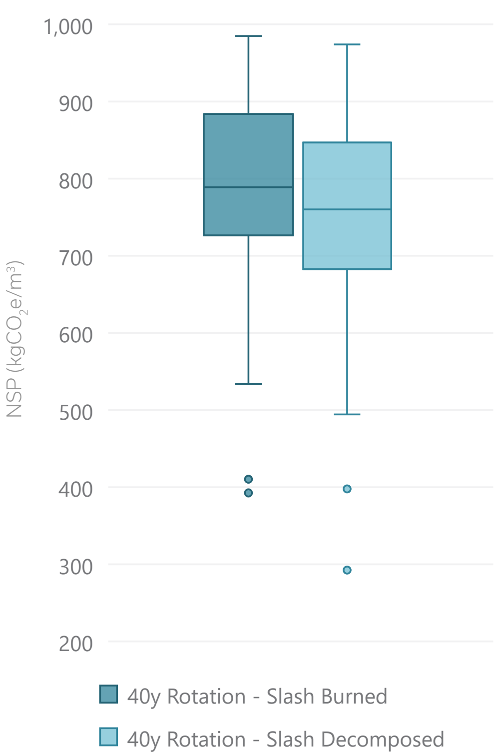
NET FOREST CARBON VIA FVS SLICING METHOD

Estimated using Carbon Released From Fire and change in Total Stand Carbon as reported from FVS simulation (includes pile burns, change in carbon in above grade biomass, below grade biomass, deadwood, litter, etc. but excludes soil).



RESULTS AND DISCUSSION

NSP is calculated for each of the 92 stands simulated. Stand conditions vary and overall results ranged from ~700 to ~850 kgCO_2e/m^3. See summary below:



Notice that the median values for the pile burn and the slash decomposition scenarios are within 3.5% of each other indicating that pile burns have roughly the same impact as decomposing slash. These results are dependent on the more detailed calculation assumptions embedded in FVS including decomposition rate. Some parameters are adjustable, however alteration of these are not recommended unless supported by robust and relevant data.

REPORTING FVS-SIMULATED NSP TO AN LCA

To use FVS results in an LCA, identify the median stand and the reporting interval at which emissions flip from net-positive (to atmosphere) to net-negative (sequestration). Sum net forest carbon prior to this inflection point and report in A1. Sum net forest carbon after this inflection point, apply your carbon discount factor, and report in B1. See the *Atmos Reporting Method* on page 7 for more.

Impact of Rotation Age on NSP

A rotation age of 60 years – as opposed to 40 years – allows a stand time to sequester more carbon to balance against biogenic emissions from harvest be it from bio-degradation or from burning.

To investigate the impact of rotation age on NSP, a comparison was conducted in our early research. Using the USDA Forest Vegetation Simulator (FVS) to model 40-year and 60-year rotations of Douglas fir in the West Cascade region, we estimated the range of Net Sequestration Potential for both scenarios. Note, this was done using a proxy NSP calculation that was not yet as robust as the FVS Simulation method presented in this paper. The results are presented here for discussion and are intended to be compared against one another only.

Results showed that on average 40-year rotations result in significantly lower net sequestration than 60-year rotations. Note that rotations can certainly be extended longer. An increase of 20 years was approximated here for demonstrative purposes.

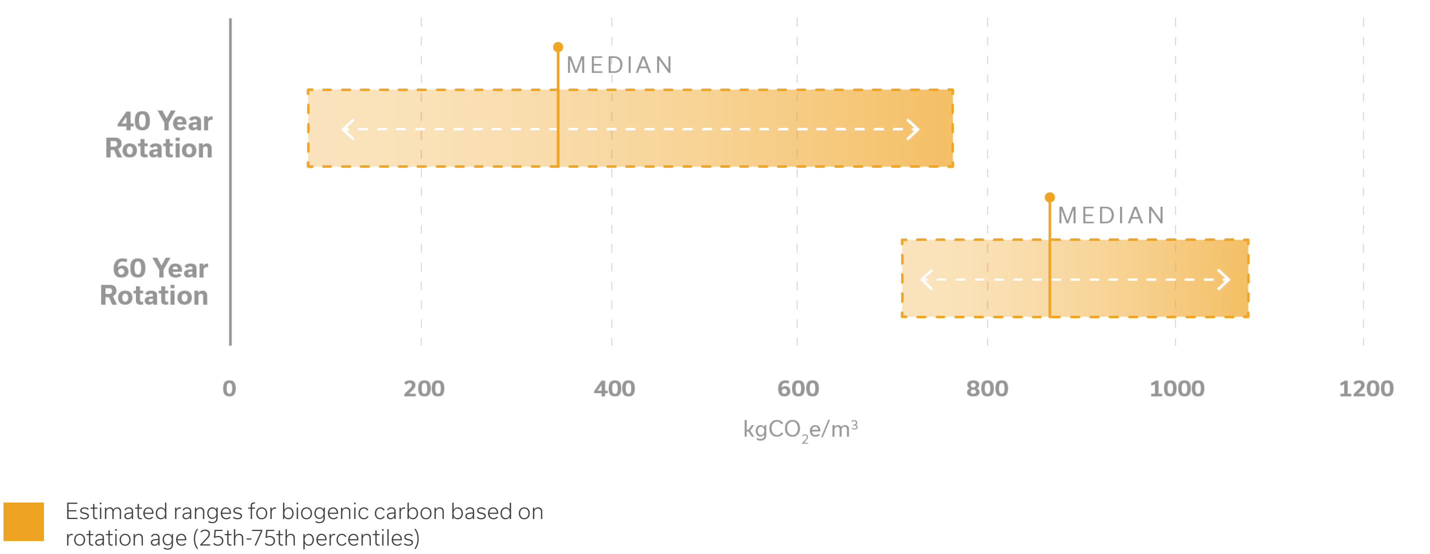
340 kgCO_2e/m^3

Median estimate for sequestration in timber under a 40-year rotation cycle.

850 kgCO_2e/m^3

Median estimate for sequestration in timber under a 60-year rotation cycle.

COMPARISON OF ROTATION AGES



Biogenic carbon as kgCO_2e/m^3 of timber. Ranges shown for 40 and 60 year rotations are based on 25th and 75th percentiles of results from 92 plots in FVS simulation. Simulation inputs assume 300 trees per acre of Douglas fir in the West Cascades clearcut at harvest with pile burn. All values displayed, including 'standard' estimate, do not account for material loss at mill and in product manufacture.

Data and Technical Limitations

Basing NSP on real-life data would be ideal but is not realistically achievable at this point in time. Current NEP and NBP data is sparse and further research is likely needed to collect and/or relate NEP data to forest characteristics and management practices in a comprehensive, usable database.

In the absence of real-life data, modeling is the next-best approach, however this limits the accuracy of results to the software's capabilities. For FVS the following constraints are noted:

- FVS is a US software designed and calibrated for forests within the United States. As such it may not be applicable internationally without customized variants.
- FVS is focused on forests and as such is suited to wood products but does not necessarily extend to other biogenic materials.
- While FVS is free and includes online tutorials, the software and subsequent data processing will require a learning curve for many.
- The carbon pools simulated in FVS do not include soil carbon. This is a large carbon pool, our understanding of which is still in early development.
- FVS has a 40 data point limitation which means that annual reporting for most forests will not be possible. As such a coarser reporting is required by lengthening the reporting interval which reduces the precision of the calculation of NSP.

Limitations of a Carbon Focus

This paper focuses on carbon accounting methodologies for forest products. It does not take into account broader ecological impacts like biodiversity, water retention and water cycles. Globally, forests provide many more benefits than just carbon storage including:

- Biodiversity Conservation: Forests are home to more than 80% of terrestrial biodiversity. They provide habitats for many animals, plants, fungi, and microorganisms, many of which are not found anywhere else.
- Water Cycle Regulation: Forests play a key role in the water cycle. They absorb rainfall, reduce runoff, recharge groundwater, and release water vapor back into the atmosphere, influencing local and regional climate patterns.
- Natural Filtration and Water Quality: Forests act as natural water filters. Tree roots and forest undergrowth slow the flow of rainwater, allowing it to percolate into the ground and reduce sediment and other pollutants from entering streams and rivers.
- Soil Conservation: Tree roots bind the soil together, preventing erosion. Forests also replenish the soil with organic material from fallen leaves and dead organisms, improving soil fertility.
- Air Purification: Trees and forests filter pollutants from the air by trapping particles on leaves and bark.
- Temperature Regulation: Forests influence temperature both locally and globally. Trees provide shade and release water vapor, leading to cooling on a local scale. At a global scale, forests help regulate the Earth's temperature by absorbing sunlight and reflecting some of it back into space.
- Windbreak and Noise Reduction: Forests can serve as natural windbreaks, reducing the speed and force of wind. They also act as buffers against noise pollution.
- Habitat Corridors: In fragmented landscapes, forests can serve as corridors that enable wildlife to move from one habitat to another, promoting gene flow and reducing the risks of inbreeding.
- Nutrient Cycling: Forest ecosystems play a pivotal role in nutrient cycling. Decomposing plant and animal matter returns essential nutrients to the soil, which supports the growth of new life.
- Protection Against Natural Hazards: Forests on slopes can help prevent landslides and avalanches. Mangrove forests act as buffers against tsunamis and help reduce the impact of storm surges.
- Cultural and Spiritual Value: Many forests are of spiritual and cultural significance to indigenous peoples and local communities. These forests contribute to the identity and traditions of countless groups around the world

These benefits are not accounted for in any energy or carbon metrics globally. If they were included, the value of forests clearly would be much higher.

KEY TAKE-AWAYS FOR THE BUILDING INDUSTRY

Wood is good, but our current approach to biogenic carbon doesn't capture the full atmospheric impact over time. Conventional LCA practice for wood products accounts for past sequestration that occurred 40+ years ago and is already realized in today's atmosphere. Typical reporting procedures also tend to down-play post-harvest emissions when they are included by canceling these out with up front sequestration. This, accompanied by an assessment scope that does not adequately reflect carbon flows at the forest results in biogenic carbon values that do not emulate forest management. Sequestration rates should differ based on forest management practice as these choices influence carbon flows at the stand.

Net Sequestration Potential (NSP) is a metric that can account for the holistic emissions from the stand. Additionally, the proposed reporting methodology presented in this paper better aligns with the intent of a building LCA to identify the potential *future* impacts of design choices. While these methods cannot illuminate impacts amongst all ecosystem services forests provide, they can help improve our understanding of the impacts biogenic products have from a carbon perspective.

For those interested in responsibly reporting biogenic carbon from wood products in LCAs, the USDA Forest Service's FVS software can be a helpful tool and presents a free and publicly available means to simulate many different forest management practices and understand their impacts.

Vision for the Future

We believe having clear visions of what is possible will help make the seemingly impossible, possible. Now imagine the following:

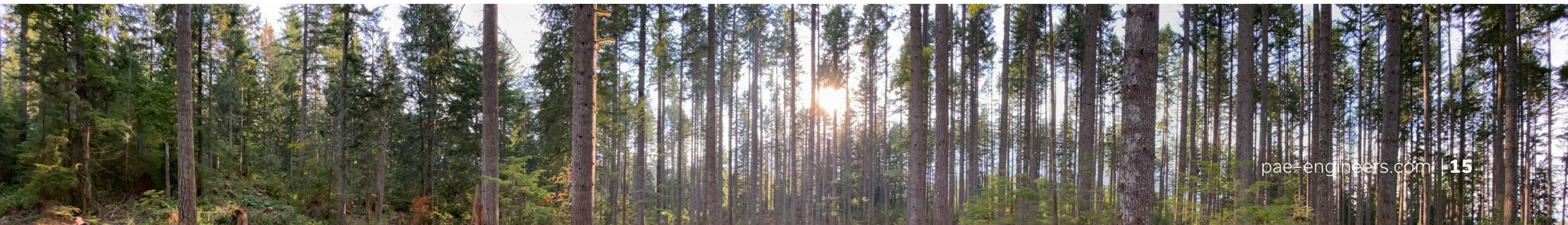
The year is 2030 and the planet is on track to solve the climate crisis by 2050. A key portion of this is the use of wood products in buildings, as it offers a method to sequester carbon and lock it away in the built environment for generations. Buildings built with wood are designed to last for at least 200 years, but are expected to last much longer than this. LCA studies now extend building lives to 200 years and beyond versus the short term thinking of the past. Wood that is procured for buildings comes from climate-smart forests that use thinning practices rather than clear cutting. This has helped make thinning forests a viable business model versus clear cutting.

Thanks to improved forestry practices, encouraged by wood procurement, forests around the planet are managed to not just optimize revenue but to also optimize carbon sequestration. Thanks to this, many forests now have longer rotation periods using thinning rather than clear cutting. These forests thus never lose their complete canopy but rather keep a partial canopy and can naturally regenerate themselves. Forests also have better soil stability and habitats to support broader ecosystem services.

These improved practices have been clearly documented in the building industry with updated standards (e.g. ISO) that formalize the net sequestration potential of wood products and other natural materials such as hemp, straw, etc. These updated standards have helped encourage better forest management, wood procurement and ultimately carbon sequestration in the built environment. Professionals in 2030 look back at the early 2020s as amazingly outdated as they overestimated the benefits of many wood products and were missing key components to measuring carbon neutrality in the built environment.

Globally, through the COP, the United Nations have set standards for sequestration rates of forestry practices. This has led to an updated system of global standards that set clear carbon sequestration rates for different wood products. These have helped drive the global forestry market away from clear cutting forests. This has revolutionized forestry practices as now forest thinning is the standard practice used for any products coming out of forest systems.

In addition to the UN, third party certification systems (such as LEED, ILFI, Passive House, Built Green, Earth Advantage, etc.) have adopted the updated standards in their rating systems, which has made a consistent metric for net zero carbon in the built environment. Thanks to this governments are also using the same methodology to regulated carbon accounting through building codes. This has been enormously beneficial so society can have the same metrics and language around what it means to be net zero carbon and beyond, to regenerate built environments. Now even grandparents and children know what net zero carbon buildings are and how they can help make them a reality.



Next Steps

Here are the next steps we see coming out of this work to help the building industry normalize metrics and encourage optimal sequestration from wood products:

- ISO standards need to be updated to formalize the net sequestration potential of wood products and avoid over-counting sequestration in the A stages of an LCA.
- Tools to speed the calculation of NSP from FVS output reports should be developed to streamline the effort.
- EPDs need to be updated to better reflect carbon stocks and flows per direction in this paper.
- Any sequestration credit needs to reflect regrowth of new forests planted to replace those that were harvested to avoid taking credit for sequestration of past decades. This should be moved to the B1 stage and discounted based on probability of successful regrowth.
- Wood that is procured for buildings should come from climate-smart forests that use ecological forest management.
- Third party certification systems (LEED, ILFI, Passive House, Built Green, Earth Advantage, etc.) adopt the updated ISO standards in their rating systems, which make a consistent metric for net zero carbon in the built environment.
- Governments use the same methodology to regulate carbon accounting through building codes handling embodied carbon requirements.

DEFINITIONS

Autotrophic Respiration | respiration from primary producers (plants)
Biogenic Carbon | carbon from biological sources and processes
Clearcut | a harvest method wherein all trees in an area are cut down
Embodied Carbon | carbon associated with the production and use of a material or product
EPD | environmental product declaration
FSC | Forest Stewardship Council
Heterotrophic Respiration | respiration from non-primary producers (e.g. microbes decomposing organic matter)
LCA | life cycle assessment
Litter | vegetative debris on the forest floor including branches and leaves
NBP | Net Biome Production
NEP | Net Ecosystem Production
NSP | Net Sequestration Potential, a measure of embodied biogenic carbon
NPP | Net Primary Production
Riparian Buffer | protected strips of land along waterways
Rotation Period/Rotation Age | the time from one harvest to the next
SFI | Sustainable Forestry Initiative
Slash | Branches and other vegetative debris left after harvest
Stand | a unit of forest area
Thinning | a harvest method where select trees are cut down and larger trees are left standing.

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LEVER ARCHITECTURE

NORTHWEST NATURAL RESOURCE GROUP

OREGON STATE UNIVERSITY

CARBON LEADERSHIP FORUM

VIBRANT PLANET

LMN ARCHITECTS

Regenerative Design Group

We're all about people and nature. Engineers have a reputation for complicating things. But at PAE, we like to keep it simple: People and nature are our driving forces. Internally, we look out for each other and the spaces we occupy—inside and out. And the same applies to our work. We design high-performing buildings that keep people comfortable, healthy, and productive inside, while restoring the natural world outside.

We believe the climate crisis can be ended in one generation. It is our mission to help make this a reality by implementing net zero carbon and regenerative solutions. A regenerative environment goes beyond net zero carbon to implement positive solutions for improved human and eco-system health. This research is part of our efforts to quantify and verify the impacts of design solutions relative to current industry standards on carbon accounting.

This paper which is part of a series of papers PAE is working on to test concepts and verify performance of solutions to help create a net zero carbon economy.

https://www.pae-engineers.com/about/regenerative-design-group

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